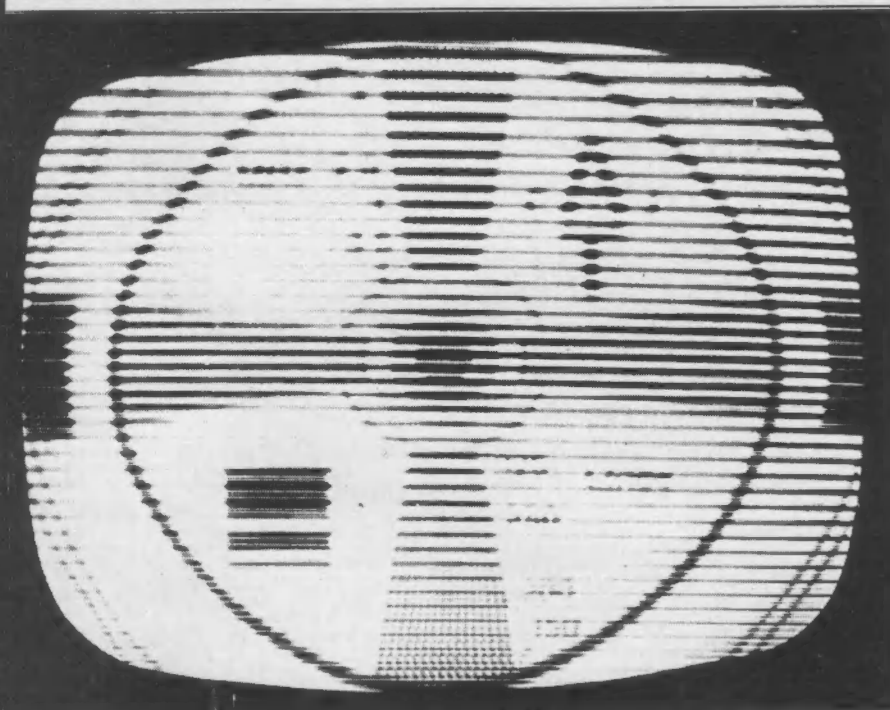


CO-CHANNEL AND ANTENNA PHASING

TECH BULLETIN 9301 / ISSUED 01 JUNE 1993

WHITHER GOEST SATELLITES:

A REPORT (01-06-93)

With the loss of Australian OPTUS B1 following a launch failure in January, the direction of satellite delivered PAY TV in the (South) Pacific has become ever more muddled. The essence of the mystery is as follows:

1) For a PAY TV service to operate there must be one or more satellite transponders (i.e., transmission channels) available from a satellite which has the technical capability to serve the intended earth-target region. Such a transponder must:
   a) Produce sufficient power to be receiveable on the ground with 'modest' home style antennas (making Ku band satellites the service-of-choice);
   b) Be priced such that a PAY TV entrepreneur can calculate how his use of the transponder will allow his business to produce a profit within a reasonable time frame (3 to 5 years typically).
2) For a PAY TV service to operate, the PAY TV entrepreneur must have access to a quantity of quality programming at pricing which will allow the business to become profitable within a reasonable time frame (again, 3-5 years).
3) For a PAY TV service to operate, there must be a method of controlling who receives the programmes, and where they are received. Such a system must:
   a) Create a relatively simple system of delivering to the subscription points (homes, taverns, et al) the hardware required to receive the transmissions, as well as a technique to collect for programming use.

At the present time there are three C-band (3.7-4.2 GHz) INTELSAT satellites to our north; 183/180/177 east. All are aged, nearing the end of their useful lifetimes; all have lost the ability to stay directly over the equator and now fly in 'figure 8' patterns requiring hour to hour tracking with dish-moving elevation motors at ground stations. Over the next 3 years two of these aging Intelsat satellites will be replaced with brand new C plus Ku band capable satellites. Additionally, a competitor to Intelsat (PanAmSat) plans to launch a similar C plus Ku band satellite in April of 1994 and it will have the technical capability to transmit one or more strong Ku band signals into New Zealand from 166/168 east (strong: capable of being received properly with dishes of 1-2 metre size).

New Zealand alone, without Australia, was unlikely to have satellite delivered PAY TV; our 'market' is simply not large enough to justify the expenses involved in establishing and operating such a service. Australia, on the other hand, is uncertain whether it wants satellite delivered PAY TV, opting instead for MDS (terrestrial microwave distribution).

Enter CDV (compressed digital video). Until 'today', if you wished to transmit more than one TV programme at a time, you needed as many transponders as you had programmes. CDV changes that. The latest CDV techniques turn analogue video into digital signals, then compresses the digital signals (much like your office computer compresses data to disc). This allows up to 10 separate TV programmes to fit into a single satellite transponder. With CDV on the horizon, the economics of delivering PAY TV via satellite changes dramatically; up to 10 programmes delivered for the today cost of one. And the horizon is near; practical CDV exists today; consumer CDV products (including TV sets) 12 months away. And it all comes together in 1994; **stay tuned!**

TECH BULLETIN 9301- Co-Channel Interference Solutions

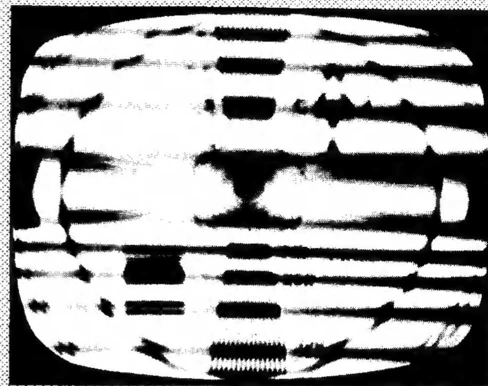
On 11 VHF channels (3 Band I, 8 Band III) New Zealand has more than 1,050 operating TV transmitters; with radiated powers ranging from 325 kilowatts to 1/10th of a watt. While the vast majority of transmitters operate with powers under 30 watts (870 transmitters), radiated power greater than 30 kilowatts is not uncommon (18 transmission channels). To fit each of these transmitters into the 11 available VHF channels, allocation engineers at the Department of Commerce juggle polarizations (V or vertical; H or horizontal), antenna beam patterns (i.e., directional to serve restricted geographic areas), and something called offsets; a technique that moves the precise transmitter frequency +/- up to 26 kilohertz from the nominal channel frequency (see footnote #1) in an attempt to reduce the objectional screen display if not the actual interference level that is bound to occur when two or more transmitters operating on the same channel arrive at a common receiving location. When two (or more) transmitters operating on the same channel can be received at one off-air site, the interference that results is called Co-Channel Interference or CCI. This typically manifests itself as horizontal lines (bands) across the screen not unlike looking at the primary picture through venetian blinds (indeed, many people call it venetian blind interference). The exact pattern of the lines/venetian blinds depends upon two factors:

1) The difference in signal strength between the two signals;

2) The precise offset employed by each transmitter, as certain offsets (i.e., difference in the two operating frequencies) create far more intense interference for a given ratio of signal levels than others.

The offset selected by allocation engineers is an attempt to minimize the severity of the venetian blind effect when there is no way to guarantee that two transmitters operating

'VENETIAN BLINDS' / CO-CHANNEL



on the same channel will not be received at a common site. And if there are three (or more) stations all on the same channel receiveable at a common off-air site? CCI or venetian blinds becomes a constantly changing pattern of both horizontal and diagonal lines resulting from the video information contained by each signal 'modulating' one another in the detector of the TV receiver. This Tech Bulletin will spell out antenna solutions to CCI interference; solutions you as a stocking installer can employ to greatly improve the quality of your customer's reception under interference conditions. Additionally, when the data contained in this Tech Bulletin is employed in conjunction with other Tech Bulletin issues, you as an installing stockist may be able to provide first-time reception to one or more sites for 'missing services' ; such as TV3.

Quality reception of any broadcast transmission requires that a single modulated waveform appear at the detector of the receiver. For example, when two (or more) AM radio stations are simultaneously heard, the speaker may emit an annoying tone; the result of the two stations slight frequency offset being detected by the demodulator. This 'beat

Footnote #1: TV transmitters are required to maintain a frequency stability of +/- .001% of their ASSIGNED operating frequency when operating with a transmitter power of 0.1 watt or greater.

note', or whistle, is a form of CCI. The relative difference in signal level between the desired transmitter (we'll call it the 'DT') and the undesired transmitter ('UT') determines the loudness or annoyance level of the 'beat note'. The actual frequency offset between the DT and the UT creates the tone of the whistle.

EXAMPLE: One AM transmitter operating on 837.0 kilohertz and a second AM transmitter operating on 837.5 kilohertz; the difference between the two carriers is 837.5 - 837.0 or .5 kilohertz (500 hertz). The frequency of the 'whistle' coming from the speaker will be 500 hertz. The tone will be as constant in frequency (i.e., 500 hertz) as the relative frequency stability between the two transmitters. The amplitude (loudness) of the tone will be determined by the relative strengths of the DT and UT signal sources, with the loudness

NEW ZEALAND TV CHANNELS / BANDS I and III

Channel Number	Bandwidth	Nominal Visual Carrier	Nominal Aural Carrier
1	44-51 MHz	45.250 MHz	50.750 MHz
2	54-61	55.250	60.750
3	61-68	62.250	67.750
4	174-181	175.250	180.750
5	181-188	182.250	187.750
6	188-195	189.250	194.750
7	195-202	196.250	201.750
8	202-209	203.250	208.750
9	209-216	210.250	215.750
10	216-223	217.250	222.750
11	223-230	224.250	229.750

OFFSETS: Precise offsets, within .001% of the operating frequency, are assigned to each transmitter operating with a transmitter power of 0.1 watt or more. In practice, precision offsets are required to reduce to a practical minimum the on-screen interference levels between two (or more) TV transmitters assigned to the same channel in a given region. Most TV transmitters are assigned 'offsets' from the following offset-blocks (chosen because study has shown these offset-blocks create the minimum on-screen disruption [venetian blind effect] to viewers):

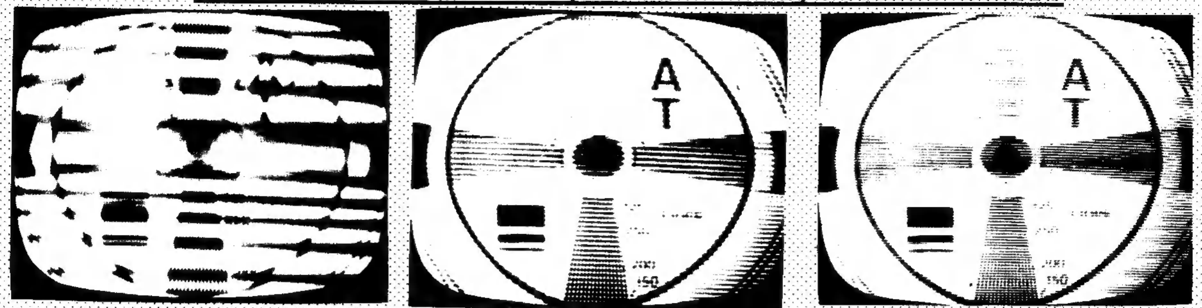
Zero Offset: i.e., channel 4 would be 175.250 +/- 100 hertz

10.4 Offset: i.e., can be -10.4 (channel 4 would be 175.239.6 +/- 100 hertz), or, +10.4 (channel 4 would be 175.260.4 +/- 100 hertz).

13.0 Offset: i.e., can be -13.0 (channel 4 would be 175.237.0 +/- 100 hertz), or, + 13.0 (channel 4 would be 175.263.0 +/- 100 hertz).

23.4 Offset: i.e., can be -23.4 (channel 4 would be 175.226.6 +/- 100 hertz), or, +23.4 (channel 4 would be 175.273.4 +/- 100 hertz).

REPRESENTATIVE CCI (CO-CHANNEL) SCREEN BEATS



(Near) 0 Kilohertz Beat (Near) 10.4 Kilohertz Beat (Near) 23.4 Kilohertz Beat

increasing as the ratio of signal levels to the receiver detector decreases; i.e., being most annoying (loudest) when the DT and UT signals are of the same approximate amplitude to the receiver detector.

Because the video portion of TV transmissions is amplitude modulated (just like our AM broadcast band example), the effect described for AM radio appears in TV transmissions as well; affecting the video portion of the transmission. The AM detector in this case is demodulating wideband video, not audio, and rather than being displayed through a speaker (as with radio) it is displayed on a cathode ray (picture) tube. The beat note we hear in an AM radio situation becomes a beat note we see on television. The horizontal lines appearing across the screen are the visual equivilent to the whistle in an AM radio system. The two carriers (DT and UT) appear at the TV receiver's detector. If one (channel 1) TV transmitter is operating on a frequency of 45.260.1 MHz while the second is operating on a frequency of 45.239.8 MHz, there is a frequency difference at the receiver detector of 45.260.1 (-) 45.239.8 or 20.3 kilohertz. Were this an AM radio system, the 20.3 kilohertz audio beat produced in the receiver detector would go unnoticed by the listener; neither the listener ears nor the AM radio's audio amplifier stage(s) would process such a high audio frequency. In the case of two amplitude modulated TV carriers, the wideband detector of the TV receiver (it must be capable of demodulating signals with a baseband range from nearly 0 hertz to more than 4,500,000 hertz) treats the 20.3 kilohertz beat just as if it were a part of the demodulated TV video information. Video amplifier stages subsequent to the detector process the beat signal along with the desired video waveform 'baseband' and the result is not a whistle in the speaker but rather horizontal lines appearing on the picture tube. The lines in the video are the same thing as the whistle in the speaker in an AM radio system. As with AM radio, two factors determine the 'annoyance level' of the lines on the TV screen; the frequency of the beat, and, the amplitude difference or ratio between DT and UT. The perceived quality of reception, given co-channel interference (CCI) conditions, can be greatly improved by 'fine tuning' either (or both) of the two conditions: i.e., the frequency of the beat, and/or the amplitude of the beat note.

1) FREQUENCY: TV transmitters (including very low power translators) are assigned precise offsets; i.e., specific operating frequencies with a precision approaching 100 hertz (.1 kilohertz, .0001 megahertz). Studies conducted in the UK and North America in the late 1940s and early 50s determined that when CCI was unavoidable, the effects or viewer annoyance levels could be improved if certain offsets were avoided. Further, the degree of viewer annoyance could be markedly impacted by selecting precision offsets which produce the

least disruptive pattern or lines on the TV screen. If the channel assignment personnel at the Department of Commerce have done their jobs properly, and if the field measurement personnel at RFS who verify operating frequencies monitor these offsets routinely, the antenna system installer will have little to say about the offset portion of the equation. On the other hand, if the beat pattern found at a receiving site is consistently more annoying than you believe it could (or should) be, a review of your particular offset situation might be in order (first contact RFS to ask if the transmitters in question might have strayed away from their assigned precision offsets).

2) AMPLITUDE : At any given off-air receiving site where two or more stations are picked up when the directional receiving antenna is pointed towards (optimized) on the desired transmitter/DT, the installing stockist can create an antenna receiving array which will minimize or totally eliminate the CCI. The weakest link in the receiving system producing CCI is the receiving antenna. The most practical solution to CCI is to eliminate it before it occurs; at the antenna.

RECEIVING ANTENNA PATTERN

Virtually all receiving antennas sold to the trade for stocking and re-sale to the home viewer have certain characteristics. It is difficult to find a TV receiving antenna that does not exhibit:

a) Gain: measured (if known) in dB but more properly either dBi or dBd.

b) Match: enumerated as 300 ohms/balanced, 75 ohms/unbalanced.

c) Pattern/beamwidth: stated as so many degrees wide at the half-power (3 dB) points in both antenna planes.

d) Front-to-back ratio: stated (if known) as so many dB.

e) Bandwidth: stated in megahertz or more commonly as band I or bands I, III, IV and V.

In most situations involving CCI the desired transmitter (DT) is arriving from one direction while the undesired transmitter(s) arrives from a different antenna pointing direction. If the receiving antenna's pattern and front-to-back-ratios were perfect, the antenna would respond (i.e., pick-up) the signal from the DT only when you are pointed towards it, and reject all UTs coming from other directions. Alas no such perfect antenna exists.

The reality is that most antennas sold concentrate on match over bandwidth rather than on optimized beamwidths and forward gain. This often makes them poor performers when called upon to reject signals arriving at the antenna from a side or rear direction. Recall that the degree of viewer annoyance is determined by the precise offset frequency between the DT and UT, and, the relative amplitude (i.e., signal strength) difference between the DT and the UT. Some background data.

a) Co-Channel annoyance vs. amplitude difference. Assuming the offset frequency has been properly assigned, we can refer to extensive viewer testing conducted in North America during the period 1956-1959 by a group known as TASO. These tests created simulated CCI and asked viewers to subjectively rate their acceptance of picture quality. Both the offset frequencies and the amplitude of the two (or more) carriers were varied over a 40 dB range while the diverse panel of viewers (young/old, male/female, professional/unskilled et al) recorded their picture quality judgements. From these landmark test results a '**TASO Scale**' has been adopted by engineers throughout the world. Our interest in that scale is three fold; a fraction of the total results.

First, we want to know how much signal level is required in the absence of CCI to create an acceptable picture for most viewers. Secondly, we want to know how much UT (undesired transmitter signal) the viewer will

TASO GRADING IN ABSENCE OF CO-CHANNEL INTERFERENCE

TASO GRADE	VIEWER DESCRIPTION	ACTUAL SNR	ACTUAL dBmV
#1/Excellent	"Extremely high quality, as good as could desire"	**40 dB**	0 dBmV/1 mV
#2/Fine	"High quality, interference perceptible"	**34 dB**	-6 dBmV/500 uV*
#3/Passable	"Acceptable quality; interference not objectionable"	**28 dB**	-12 dBmV/250 uV*
#4/Marginal	"Poor quality; you wish you could improve it. Interference somewhat objectionable"	**22 dB**	-18 dBmV/130 uV*
#5/Inferior	"Picture very poor (no colour), but you can watch it. Interference definently objectionable"	**16 dB**	-24 dBmV/63 uV*
#6/Unuseable	"Picture so bad you cannot watch it"	**10 dB**	-30 dBmV/32 uV*

Note: Worldwide a signal level of **0 dBmV** (1,000 microvolts/60 dBuV) at a Signal to Noise Ratio (SNR) of **40 dB** is accepted as a target signal level to deliver to a TV set input terminals. ***/ uV** here means microvolts.

tolerate when the offset frequency is optimized, and conversely, how much UT can be tolerated when the offset signal is not optimized. We will do this in various forms of dBmV scales; i.e., decibels above or below one millivolt on your signal level/field strength meter where the standard reference level is 0 dBmV (which is the same as 1,000 microvolts or 1 millivolt).

b) TASO Grades. Without CCI, viewers were asked to rate the quality of pictures while the signal + noise to noise ratio was varied. In this test, the noise figure (i.e., threshold or floor) of the receiving system is measured and known to the engineers. The received noise is the sum of:

1) Any noise contributed from the antenna system (i.e., power line, electric stock fence, etc. radiated broadband noise).

2) Any noise contributed by the receiver's RF/IF amplifier stage(s); i.e., the receiver noise figure within the bandwidth of the TV signal.

In the tests, the signal is injected into the receiving system at precise amplitude levels; such as 40 dB greater than the receive system noise floor. In a separate quantitative measurement, the actual signal levels (in microvolts or dBmV) were then deduced for the various signal + noise to noise ratios (SNR) as a guide to receive system planners (see Tech Bulletin 9302 for further discussion of these tests; pages 8 and 25). A table on page 5, here, summarizes the findings.

c) TASO GRADING With CCI. Now that we understand the basics of TASO grading, what degradation does co-channel interference bring to the viewer? There are three variables here.

1) Offset 'beats'. Tests tell us certain offsets are 'taboo'; i.e., the annoyance level is far worse (for a given DT to UT amplitude ratio) than with the desireable offsets. Unfortunately for the installer, offsets are out of his control (established at the respective transmitters) although 'tweeking' of the frequency control circuits at the transmitter site can certainly vary the offset.

2) Signal plus noise to noise ratio. It is interesting that as the signal level from the DT goes down (i.e., becomes weaker), the ill

effects of the interfering carrier signal may become less noticeable. The same thing obviously happens if the signal level from the DT is more or less constant while the signal level from the UT fades up and down; the result of changing on-path weather conditions or freakish long distance skip from hundreds of miles distant.

a) As the table below relates, we need the greatest possible amplitude difference between the DT and the UT in order to reduce the visual impairment of CCI. The installer may need to consider increasing the gain of the overall antenna system in the direction of the DT as a partial solution to CCI. We'll see why shortly.

3) Ratio of the Desired Transmitter (DT) signal to the Undesired Transmitter (UT) signal. If the normal antenna for the site in question is not rejecting the UT signal, the installer must create a new receiving antenna system which has been engineered to reject the CCI UT source at the antenna.

NOTE: While hardware does exist to reduce the undesireable effects of CCI at the TV set rather than at the antenna, such systems are notoriously difficult to tune, require considerable day to day minding (i.e., tweeking) and are seldom suitable for a typical consumer. The preferred solution to CCI is to design, install and if required 'tweek' the off-air antenna system so as to reject the UT signal source(s) **before** the receiver. That is the focus of the balance of this Tech Bulletin.

The table appearing below shows the CCI test summary. On average, the viewer would be protected from picture degradation caused by co-channel interference by 24 dB more if the offset frequency of the interfering transmitter was controlled precisely. As an illustration, see the TASO Grade 4 (marginal) entry. From the table on page 5 here, we know a Grade 4 picture is in the region of 22 dB SNR at a level of around 130 microvolts (-18 dBmV). A signal 37 dB weaker (i.e., -55 dBmV or 1.8 microvolts) from a non-desired station will seriously degrade the already noise-degraded picture if the non-desired signal is on a poorly chosen offset. However, if the offset is moved to an optimum frequency, the interfering carrier can rise to a level only 13 dB below the (already weak) -18 dBmV signal before there is serious degradation.

So in fact interfering signal levels too weak to detect, even with test equipment, will 'appear' as co-channel interference when the offset

TASO GRADING / PICTURE QUALITY WITH CCI PRESENT

TASO GRADE	dB ADVANTAGE OF 'DT' OVER 'UT' AT: Most Desireable Offset	Least Desireable Offset
#1/Excellent	31 dB	55 dB
#2/Fine	25 dB	49 dB
#3/Passable	19 dB	43 dB
#4/Marginal	13 dB	37 dB
#5/Inferior	7 dB	31 dB
#6/Unuseable	not feasible	25 dB

NOTE: When the frequency offset is most desireable an excellent grade picture will remain excellent down to a ratio of (-)31 dB between the desired carrier and the undesired carrier. If the frequency offset is least desireable TASO test viewers judged the picture excellent only down to a level of (-)55 dB for the desired carrier to the undesired carrier. Note as signal quality (SNR) deteriorates, CCI may become a less important factor; an example of two wrongs making a right!

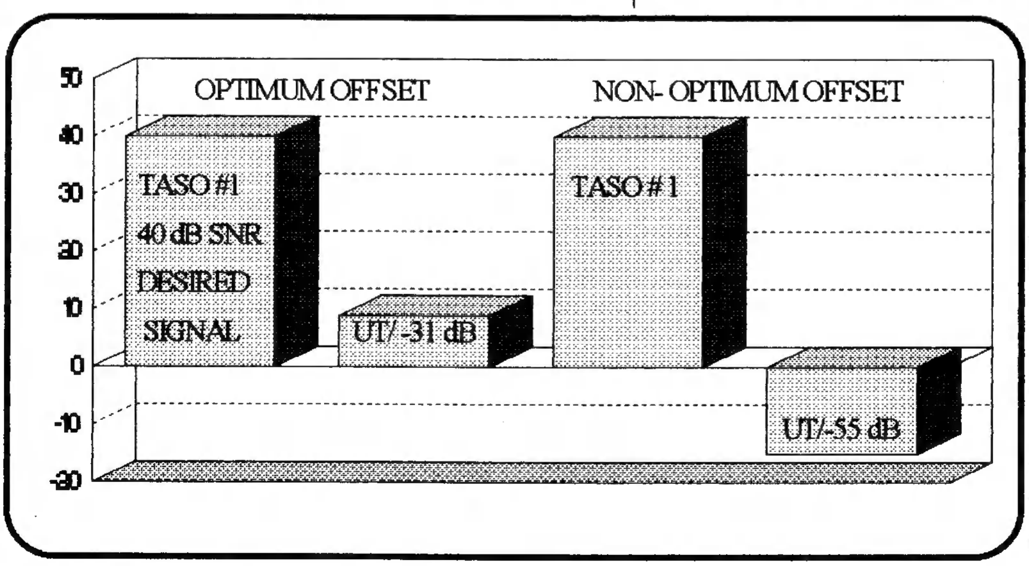
frequency between the two carriers is not optimized.

MAXIMIZING ANTENNA GAIN

In the serious antenna design world, all antennas have their forward gain referenced to something called the isotropic antenna. In other words, if a professional antenna manufacturer says his antenna has 10 dB of gain, he is advising you that if you compared the gain of his antenna (in the frequency band specified) to an isotropic antenna, his antenna would have 10 dB more gain than the isotropic reference antenna. The isotropic antenna is a mathematical reference; you cannot build one, nor hold one in your hand. It exists only on paper as a 'mathematical model'. The isotropic antenna is a point source (like this • on the paper) which has the real-world impossible task of radiating equally in all directions. The nearest reference antenna you can build or hold in your hand is the resonant dipole; a simple halfwave (length) antenna that radiates equally in directions perpendicular to the element. Antenna manufacturers find it more convenient to construct a test/reference dipole for the frequency (channel) in question and then compare their gain antenna to the test dipole. The dipole, however, has gain when it is compared to the isotropic model. So when a manufacturer makes a gain claim (which you, the installing stockist, depend upon for accuracy), you should be clear whether the gain is referenced to an isotropic model, or, a dipole. The difference is 2.14 dB. That is, a dipole in the real world has 2.14 dB more gain than the isotropic model. A manufacturer who wants his antenna to look better on paper (i.e., on spec sheets) than a competitor may quote his gain as dBi (dB gain reference an isotropic model) rather than dBd (dB gain reference a resonant dipole). A detailed discussion of this appears in Tech Bulletin 9302 but cannot be totally ignored here for reasons soon to be obvious. If your installation problem is in an area with generally weak reception (i.e., below TASO Grade 3), you already know that part of your customer's viewing problem can be traced to too-little-signal from the DT. So some quick basic data relating to improving the signal level from the desired transmitter (DT) before delving into antenna rejection of the undesired transmitter(s) (UT). Consider these numbers:

1) Measured signal level (with FSM/SLM) from desired transmitter = -20 dBmV (100 microvolts).

2) Measured signal level from undesired transmitter with the antenna pointed at the undesired transmitter = -30 dBmV. That is a 10 dB ratio between desired and undesired. However, when you rotate the antenna towards the desired transmitter the undesired transmitter drops off appreciably. And, you measure it as approximately -45 dBmV (6 microvolts). Now you have a ratio between DT and UT of 25 dB (ie., -45 to -20 dBmV). TASO would grade this as between passable and marginal in a



best-case offset or between inferior and unusable in a worst-case offset situation. The likelihood is you would be closer to inferior than passable since we have both co-channel interference and weak signal levels to deal with here. In our just stated example, the first challenge is to raise the signal level of the DT.

1) The antenna manufacturer says there is 10 dB of gain with the antenna we are using. From Tech Bulletin 9302, we know by doubling the frontal area (i.e., size of the antenna array) we can expect to gain 2.5 dB additional signal. Or by quadrupling the antenna, we can expect to gain 5 dB of additional gain (over the first, single, antenna).

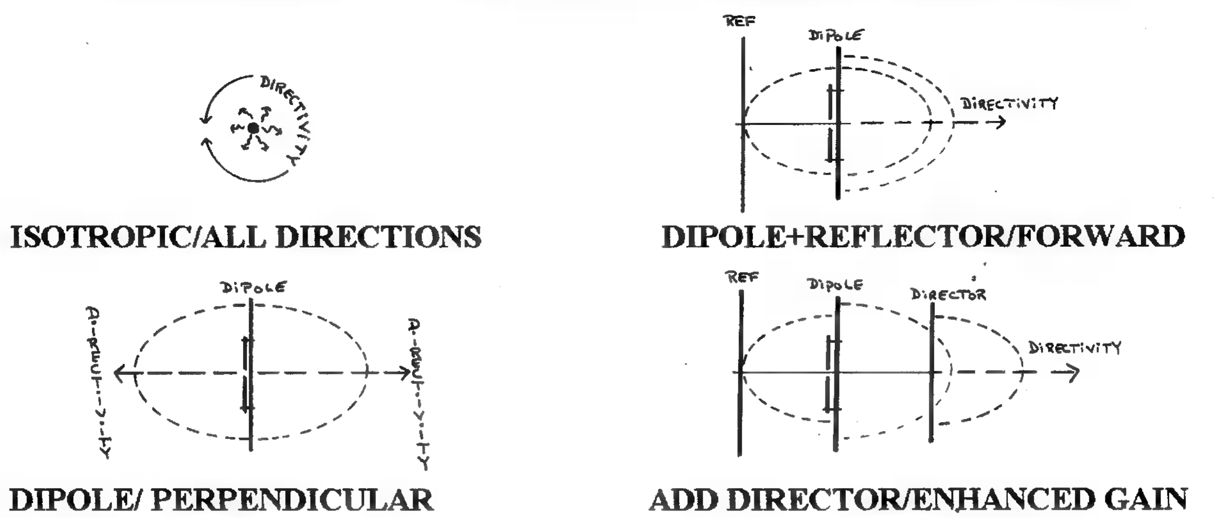
2) The installation could also be improved with a mast head amplifier. We'll see how a 20 dB gain unit with a 2 dB noise figure affects the performance of our 'system' in Tech Bulletin 9302. Of course the masthead amplifier is going to increase the amplitude of everything the antenna array receives; that includes any background noise in the area, plus the undesired co-channel interfering station. We'll return to these numbers. First, a more serious challenge is to reduce the level of interfering signal at the antenna.

ANTENNA PATTERN

Remember our mythical modeling antenna, the isotropic source/point? And the more practical reference antenna, the resonant dipole? The dipole obtains its 'gain' over the isotropic point source by eliminating the isotropic's "radiates equally well in all directions", replacing that with "radiates equally well in directions perpendicular to its element". Think of an isotropic point as a three dimensional pool of water with a pebble dropped into the water. The splash goes up and down, left and right; in fact it goes outward away from the point of pebble impact equally in all directions; similar to a sky rocket exploding high in the air. Now think of the dipole as a two-dimensional antenna. You drop it onto a pool of water, flat side down, and small ripples/waves radiate outward from the point where the dipole strikes the water but primarily perpendicular to the axis of the dipole metal element; there is almost no ripple nor wave created by the end tips of the dipole. The dipole has gain over an isotropic point source because it eliminates any radiation from the ends of the antenna, redirecting the radiation pattern in two directions; each perpendicular to the plane of the element. Now add a new element to the antenna, parallel to the dipole and slightly longer (physically) than the dipole. This longer element acts as a reflector to block antenna gain (sensitivity) in the direction/plane of the dipole + reflector. With a reflector in place, the dipole now receives 'equally well in one direction'; squirting away from the dipole in the direction not blocked by the reflector.

Next add one or more elements away from the dipole/reflector, each shorter than the dipole and progressively shorter the further they are placed from the dipole. These are called directors and the combination of a reflector and (multiple) directors cause the signal beam to become thinner and thinner; more directive, more focused in the desired (front) direction. As the antenna designer adds more elements (assuming they have been added with some knowledge of where they go and how they interact with one another), the pattern of the antenna becomes more sensitive to signals arriving from the frontal (favoured) direction and more importantly, less responsive to signals arriving from the sides or perhaps the rear of the antenna. ALAS - this additional forward gain comes with a price. Think of a latex balloon filled with water to the point of being over filled. Take the balloon in your hand and squeeze the latex; the water shifts inside the balloon and moves to a portion where your hand is not exerting pressure. This portion of the balloon grows larger while the portion you are squeezing becomes smaller. The increase in balloon size in one direction is like your antenna as you add additional directors(elements). Each newly placed director reduces the gain to the

THE EVOLUTION OF ANTENNA GAIN / SHAPING THE PATTERN



rear and sides, while increasing the gain towards the 'front'. With proper skills the antenna designer can maximize the forward gain and cause the directional antenna to have less and less 'response' to the sides and rear. This is the basis for controlling CCI; 'shaping' the antenna pattern so as to reduce to a minimum the antenna's ability in the direction of the UT while maximizing its gain towards the desired station; at the front of the antenna.

And the 'price'? Each director element increases the physical size of the antenna and can reduce the bandwidth of the antenna (remember our TV channels are 7 MHz broad at VHF; 8 at UHF). It is possible to add too many directors and defeat the entire purpose of the antenna system!

STACKING ANTENNAS /MORE GAIN

If the antenna designer can add too many gain-enhancing director elements and overshoot his performance target (see Tech Bulletin 9302), but you need additional gain for a system, how is it done? The answer is stacking or, as it is also known, phasing two or more antennas together. The concept of stacking/phasing antennas together into a single antenna array is basic to antennas. If a single antenna of certain physical size and characteristics will create 10 dB of gain in the favoured (front) direction, a second antenna electrically phased to the first will produce almost (but not quite) twice as much received signal voltage. In theory, you will gain 3 dB more with a second antenna but in practice some of that gain is lost in the phasing system (see Tech Bulletin 9302 for a discussion of how this works). The rules for 'stacking' gain follows:

1) Both antennas must be identical in physical shape and size;

2) The 'distance' from the transmitter to each antenna must be as close to identical as possible;

3) The antennas must be electrically connected together in such a manner that the signal voltage from one adds to the signal voltage picked up by the second antenna (that's where 3 dB comes from; a doubling of the signal voltage as presented to the transmission line going to the TV set).

NOW - let's consider a unique situation where the two antennas are not the same physical distance from the transmitter. If you erect a metal pipe vertically and place one antenna at the top of the pipe, and the second antenna down say 1 free-space wavelength below the top antenna, because the pipe support

is common to both and is straight up and down, the two identical antennas will have their respective directors, dipole elements and reflectors dead-in-line with one another if viewed from below (or above). This is a common way to stack two antennas for the additional (2.5/3.0 dB) stacking gain. And, both antennas are the same distance from the transmitter. To connect the two antennas together (i.e., to phase as in adding the output voltage of one antenna to the output voltage of the other antenna), we can use parallel rods of tubing or wire (called stacking lines/phasing bars), or, we can use two identical lengths of the same coaxial cable (called phasing lines) connecting each antenna into a two-way signal splitter (using the splitter as a signal combiner). We'll elect to use two identical lengths of foam type RG-6/U here. If the antennas are 300 ohm, we install a 300 ohm / 75 ohm outdoor matching transformer at the antenna connection point for both antennas. Then we cut two identical lengths of RG-6/U, long enough in each case to reach from the 75 ohm output of the matching transformer to the two-way splitter/combiner which is attached to the antenna mast precisely half way between the two antennas. With weatherproof F fittings on both ends of the cable, we now have the two antennas electrically connected together through the combiner. Each antenna captures signal sending it through the matching transformer to the two-way combiner (understand that an outdoor two-way splitter, connected up backwards, becomes a two-way combiner in this application), and then the combiner outputs the two signals in phase with one another through its one remaining (output in this case) port. The performance of the antenna system could be as shown at the top of page 11.

Now the CCI challenge. We wish to deepen the antenna system rejection for a CCI UT arriving from approximately the rear of the antenna. The antennas alone offer but 20 dB of front -to-back ratio; i.e., signals arriving at the dipole element from the rear of the antenna are attenuated by only 20 dB reference the same signal coming to the antenna from the front. Phase is the answer.

Remember that when we stack two identical antennas great care is taken to insure the signal captured by the dipole on one antenna gets to the combiner in phase with the signal captured by the second antenna. This means the desired transmitter signal from the front of the antenna array, and, whether we like it or not, also the undesired transmitter signal approaching from the rear of the antenna. Suppose we installed the two antennas in such a way the undesired transmitter signal arrives at the combiner box out of phase with itself? What then? The two antennas cancel one another; the undesired signal is simply phase-cancelled at the antennas! Here is how that is done.

1) The top antenna is mounted in the standard way.

2) The bottom antenna has new holes drilled in the boom so the boom to mast clamp sits in a position that causes the bottom antenna to mount on the mast 1/4 wavelength behind the top antenna. If we connect the two antennas together using identical lengths of RG-6/U, the desired signal and the undesired signal will arrive at the combiner 90 degrees (one-quarter of a phase cycle; there being 360 degrees in a complete phase cycle) out of phase with each other. And now we are approaching a solution.

4) The phasing lines are now length-adjusted. Rather than making both lines exactly the same length, we cut the two lines so that one is electrically 1/4th wavelength longer than the other. In the accompanying diagram (page 11) we show this as 'X' and 'X + 1/4 wave'.

5) The longer line goes from the top (normally mounted) antenna to the combiner. The shorter line goes from the bottom antenna (which is physically 1/4 wavelength behind the top antenna) to the combiner.

Think about it.

COMPARATIVE PERFORMANCE / SINGLE vs. TWO-STACK YAGI ARRAY

Array	Gain	Beamwidth/Hor.	Beamwidth/Vert.	Front-to-Back
10 el. Yagi	10 dBd	65 degrees	60 degrees	20 dB
10 el. X 2	12.5 dBd	65 degrees	40 degrees	20 dB

A signal from the front of the antenna array goes into the top antenna 1/4th wavelength (90 degrees) before it goes into the bottom antenna. Then the signal from the top antenna goes through a length of coaxial cable that is an additional 1/4 wavelength (90 degrees) longer (electrically) before it gets to the combiner. By being 1/4th wavelength in front, it is out of phase by 90 degrees with the bottom antenna. But, by going through an additional 1/4th wavelength of RG-6/U, it arrives at the combiner phase adjusted with the DT signal coming from the bottom antenna (i.e., 90 degrees faster at the top antenna, 90 degrees slower at the top antenna + coax; net result 0 degrees change). The two antennas still add signal together because they are still in phase for a forward direction signal.

And the rear arriving signal? It arrives at the bottom antenna first because the bottom antenna is 1/4th wavelength closer to the signal source. 90 degrees in time later it arrives at the top antenna where it must go through an additional 1/4 wavelength (i.e., 90 degrees in phase) delay on the way to the combiner. Now the top antenna UT is 180 degrees out of phase with the bottom antenna UT and the two signals cancel; electrically, cleanly. This technique works very nicely with the following caveats:

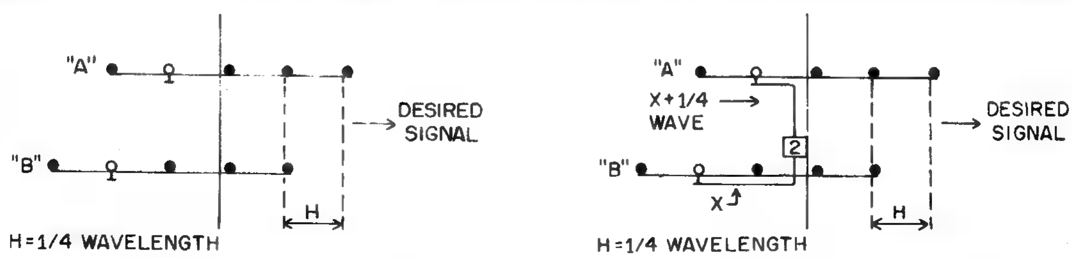
1) The UT signal should fall someplace between 165 and 195 compass degrees of the DT (i.e., point your antenna at the DT and call this 0 degrees. Now use a compass and map to determine whether the UT will approach the antenna array at an angle [reference the DT] of between 165 and 195 degrees; essentially off the back of the antenna. If it will, this will work for you, eliminating the CCI source by as much as 20[+] dB.)

2) You can also use this technique for eliminating a non-desired adjacent channel signal (say you want a channel 7 signal and there is a stronger channel 6 [and/or 8] signal off the back side of the antenna); with a 3 dB penalty for off-channel use. Arrange the antennas exactly as you would for same-channel configuration, except as follows:

a) Offset-mount the bottom antenna by 1/4 wavelength on the adjacent (non-desired) channel (not the desired channel), and,

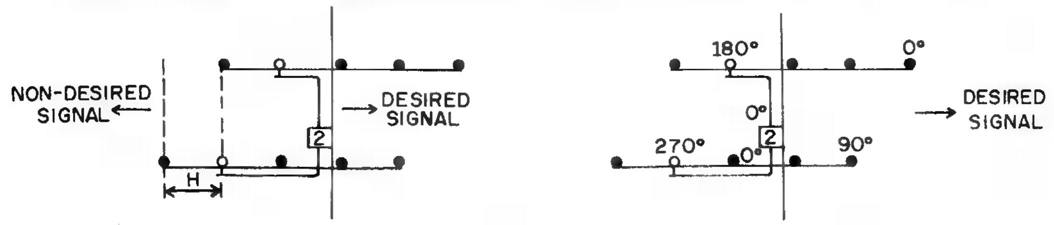
b) Cut the cable length 1/4 wavelength longer on the non-desired channel, not the desired channel.

STACKING YAGIS FOR REJECTION OF REAR-DIRECTION CO-CHANNEL



Non-desired signal is placed 180 degrees out-of-phase by bottom antenna offset and delay in 1/4th wave of coaxial cable

REAR-SIDE SIGNAL IS REJECTED BY ARRIVING AT COAXIAL COMBINER OUT OF PHASE THROUGH ELECTRICAL AND COAX-DELAYS



NON-REAR OF ANTENNA / PHASING

Of course not all UT signals arrive at the receiving site from the rear (i.e., +/-15 degrees of straight off the back of the boom). The solution for such angles of arrival is still phasing but the technique is different. The antennas are not stacked one above the other (i.e., vertically) since it would be difficult to achieve any type of phase difference in this configuration. Rather, the identical-in-design antennas are placed side-by-side in a horizontal stacking format. If you followed the rear UT phase cancellation, you'll have no difficulty with the horizontal two-stack. The key is to find a horizontal distance, along a common antenna mounting boom (a piece of horizontal pipe mounted against a tower face; or, a flat roof line where you can mount antennas in a horizontal line at will), where the distance equals 180 degrees of phase cancellation for the UT source. The magic distance in free space is 1/2 wavelength, adjusted to the actual difference in angle-of-arrival between the two signals. We call this distance 'H' (see diagram page 13). Here's how it is calculated:

1) Use a map and determine the beam heading from your receive site to the desired transmitter. Let's say it is +10 degrees with 0 degrees true-north.

2) Now calculate the beam heading to the undesired transmitter. In this example it is 35 degrees true.

3) The difference between the two is 35 minus 10 or 25 degrees of angle.

4) Go to Graph 1 here which reveals a 25 degree angle difference requires a horizontal spacing between the two identical antennas of 1.22 wavelengths.

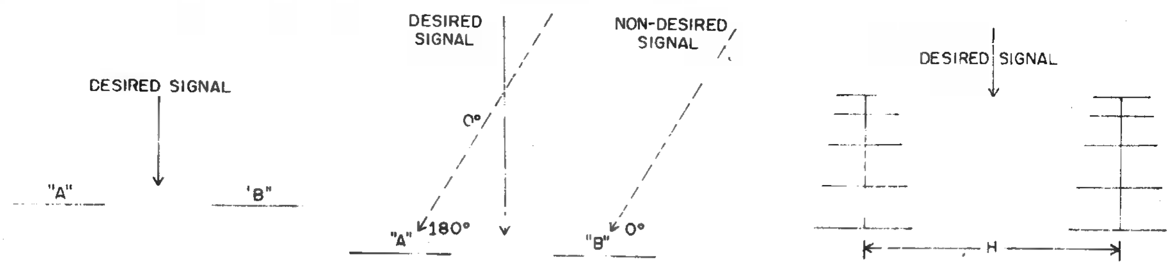
5) Now, in our example the channel of interest is 4 where one wavelength in free space (see Table 1) equals 1.717 metres (65.7"). The two identical antennas would then be mounted on a horizontal cross-arm, both pointing directly at the DT, spaced apart 1.717 metres times 1.22 (distance; Graph 1) or 2.095 metres boom centre to boom centre (distance H). The antennas would be phased with two identical lengths of RG-6/U to a two-way outdoor weather protected hybrid combiner (splitter used backwards).

NOTE: With this technique, no difference should exist in the lengths of coaxial cable connecting each individual antenna to the combiner. What does change with each channel change or each angular difference change is the spacing (distance H) between the two antennas. Also observe in Graph 1 that as the spacing between antennas reduces down to 0.75 wavelength, the Graph jumps to a greater physical spacing of nearly 2.25 wavelengths to insure adequate physical separation (i.e., so two antennas do not touch each other).

CHALLENGES

When your antenna receive site requires more forward gain than can be provided with two (identical) antennas (stacked), you are headed for four or even eight antennas in a more complex array. It is not uncommon in North America and Europe to stack four identical antennas horizontally; that is, all in a line on a perhaps quite long boom. This is a

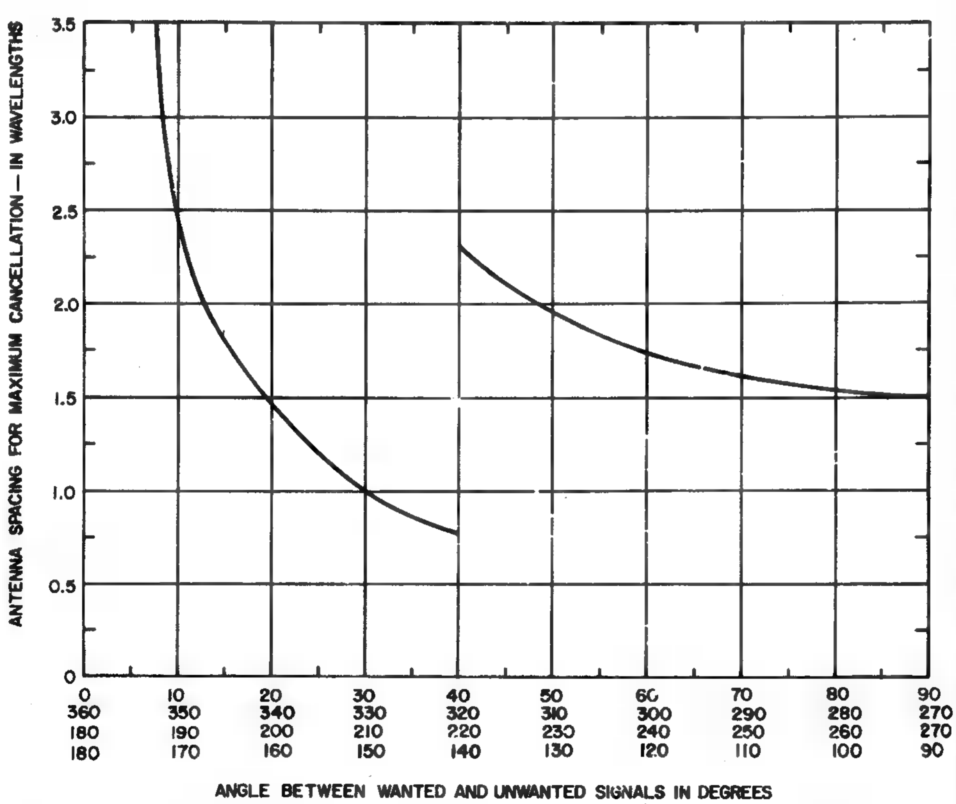
TWO IDENTICAL ANTENNAS SPACED ON SAME PLANE/HORIZONTAL LINE



Elements Face 'DT' | 'UT' Arrives At Side-Angle | Distance 'H' (Graph + Table)

perfectly adequate approach for increasing forward gain but not when you are also attempting to eliminate or reduce a co-channel signal source with precise horizontal (antenna boom-to-boom) spacing. Because any individual yagi (or log) antenna exhibits a complicated antenna pattern (i.e., small lobes of signal response that 'squirt' out of the antenna at unpredictable angles), when four or more antennas end up in a horizontal line, these essentially unpredictable minor lobes often end up 'combining' towards a co-channel source; inspite of your efforts to select a precision spacing between antennas to create a null. If you find yourself in a CCI situation that requires more gain than two yagis will provide, consider upgrading to larger yagis. Where five elements (reflector, dipole and three directors) may produce as much as 7 dB of gain (reference a dipole), a properly designed ten element will usually produce 10 dB of gain. That says a pair of well designed ten elements can offer the same gain as four 5-element yagis in a phased array. And should you still be short of gain, the co-channel problem must be tackled with

GRAPH ONE



Find correct angle (bottom); match to antenna-antenna spacing (left)

TABLE ONE / REFERENCE MEASUREMENTS FOR ANTENNA STACKING

TV Channel	Video Freq.	1/4 Wave/Space	1/4 Wave/Cable(*)	1 Wave/Space (**)
1 [TV	45.250	1.656 metre	1.358 metre	6.624 metre
2 band	55.250	1.357 "	1.112 "	5.428 "
3 I]	62.250	1.204 "	0.987 "	4.816 "
4	175.250	0.428 "	0.351 "	1.717 "
5	182.250	0.411 "	0.337 "	1.644 "
6 [TV	189.250	0.396 "	0.325 "	1.584 "
7 band	196.250	0.382 "	0.313 "	1.528 "
8 III]	203.250	0.369 "	0.302 "	1.476 "
9	210.250	0.357 "	0.292 "	1.428 "
10	217.250	0.345 "	0.283 "	1.380 "
11	224.250	0.334 "	0.274 "	1.336 "
27	519.250	0.144 "	0.116 "	0.576 "
45	679.250	0.110 "	0.091 "	0.440 "
62	799.250	0.094 "	0.077 "	0.376 "

*/ 1/4 wavelength in cable calculated for 0.82 velocity of propagation factor (cable) such as 7 Foam Series or 11 Foam Series by Paramedrop.

**/ 1 wavelength in space utilized when calculating H or horizontal spacing between antennas for CCI nulling; per dimension H (diagram, page 13). Multiply 1 wavelength in space distance (this table) times the antenna spacing for maximum nulling number from Graph 1 to determine physical distance of H.

a so-called 'box' or 'H Frame' array stack as shown on page 15. Four antennas are stacked, two side by side and two more above the first two. For 8+ antennas, contact us.

Note: You cannot combine antennas in this array using a single four-way combiner; a trio of 2 way combiners with all RG-6/U lines of the same length must be used. The vertical (up/down) stacking distance should be no less than .75 wavelength in free space for antennas of up to 5 elements; 1 wavelength in free space, or the length of the boom (whichever is greater) for antennas of more than 5 elements. Selecting and stacking multiple yagi or log arrays for maximum gain, as well as matching them with appropriate masthead amplifiers is carefully studied in Tech Bulletin 9302.

GAIN NUMBERS

Let's summarize the dual-challenge problems of a typical fringe area receiving site with co-channel interference.

First - the site suffers from low signal levels arriving from the desired transmitter (DT). Minus co-channel as a degradation factor, we should have no less than 250 microvolts (uV) or -12 dBmV to produce a TASO Passable Grade picture (28 dB signal + noise to noise ratio; see Tech Bulletin 9302.)

Second - with co-channel interference, the additional degradation can reduce the apparent TASO grade picture by some amount. The degree of degradation depends upon (a) the signal ratio between the DT and the UT when the antenna is pointed at the DT, and, (b) the frequency difference (i.e., tone) of the offset.

Keep in mind that with a constant ratio in amplitude (signal levels) between DT and UT, the degradation of the co-channel can be reduced or increased as much as 24 dB simply by tweeking on the transmitter oscillator to move the offset frequency by as little as 260 hertz (!). If you suspect the offset could be improved, talk with your regional RFS office.

The low signal level from the DT can be enhanced by increasing the capture area of the receiving antenna; two properly designed 5 element yagis, for example, produce 2.5 dB more signal than a single yagi. Or, a properly designed ten element yagi can produce from 2 to 3.0 dB more gain than a single five element yagi. There is a caveat; properly designed. Merely adding more (director) elements is no guarantee the larger antenna will outperform (or even perform as well as) a smaller antenna. Your success as an installer depends upon the quality of the antennas you select.

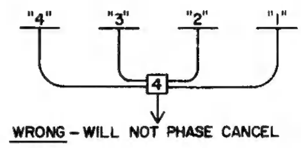
The low signal level can also be enhanced with a masthead amplifier. To be effective, the masthead unit should have a noise figure that is appreciably better than the noise figure of the TV set tuner; and, no less than 20 dB of gain (see Tech Bulletin 9302).

Unfortunately, a masthead amplifier and/or a larger capture area antenna will increase the amplitude (level) of the UT co-channel source as well as the desired transmitter unless the antenna is configured to reduce (phase out) the UT source.

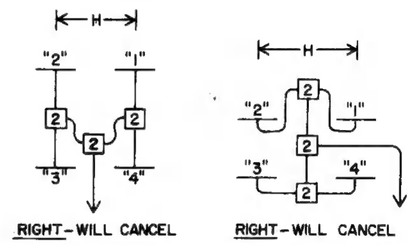
ERRATA

The same phasing techniques will also be effective in eliminating multi-path ghosting after you determine the angle of arrival of the delayed-in-time ghosted signal. Treat the deflected (ghost) path just as if it were a co-channel signal source doing the same computations as outlined here. Note however that when the DT and the UT signals arrive at the receiving site with arrival-angle differences of less than 10 degrees, phase cancellation with precision horizontal-horizontal spacing is not possible.

YES AND NO / 4 BAY PHASING



NOT THIS WAY!



OK THIS WAY

TECH BULLETIN TOPICS

TB9301: Co-channel elimination, antenna phasing techniques [Release date 01-06-93]
TB9302: Weak signal techniques, antenna + masthead practices [Release date 01-06-93]
TB9303: UHF weak signal techniques; parabolic dish construction to 6m diameter [Release date 15-07-93]
TB9304: Identifying and curing television interference sources [Release date 15-09-93]
TB9305: Master/community aerial techniques on a budget [Release date 15-11-93]
Tech Bulletin is distributed by mail to subscribers; full details appear on pages 17 and 18 here.

ASK COOP

Robert B. Cooper began a professional career in weak signal TV reception in 1956 as U.S. magazine **RADIO ELECTRONICS** engaged him to prepare a regular feature column on this subject. Creator of 15 books, more than 2,200 magazine articles, 'Coop' is now a resident of New Zealand's Far North where he continues to research and write.

• " TV3 claims to reach 87% of New Zealand TV households and say by adding 13 new transmitters in 1993, they will then reach 93% of Kiwi homes. Is this true?"
B.H., Warkworth

Probably not. But TVNZ beats them to death in the marketplace by reminding potential advertisers TV's 1 and 2 reach a claimed 96% of homes in the country while TV3 reaches less than this. A story in The Herald 21 April claimed 13 new TV3 transmitter sites, on-lease from TVNZ subsidiary BCL, will reach 200,000 new people (not homes). They also said this represents an increase of 6% in people reached for TV3 'by year end'. Unfortunately, reaching a level playing field with TVNZ is an impossible dream for TV3; TVNZ was there first, got all of the best channels and transmitting sites, and TV3 has to accept what was left over. **The aerialist can help level the field by creating home antenna systems designed to bring TV3 into areas where they may never have local transmitters. The cover (mailing sheet) for our TB9302 lists 14 (not 13) new TV3 transmit sites, their powers, channels and expected start dates.**

• **"I understand those pubs and motels with Aussat Ku band dishes no longer get Austrialian TV sports. What happened?"**
B.E., Orewa

Aussat launched 3 Ku band satellites from 1985-87. With a finite lifetime, they were scheduled for replacement under the new name Olympus. The first Olympus was to replace Aussat bird A1; the second A2. Bird A1 had the HACBSS domestic-to -Australia (ABC) service which 'spilled over' into New Zealand (using 4+ metre dishes). Pubs, clubs imported special IRD Australian receivers to decode the scrambled broadcasts.

This past January the switch from Aussat A series to Olympus B1 took place. The transmit antennas on B1 are 'tight', restricting coverage outside of Australia. Where A1 'spilled over', B1 does not; end of our access to HACBSS, at least for the time being. B series birds do have (5) specific-for-New Zealand transponders on board but nobody willing to use them.

Oh yes, the launch of B2 failed (45 seconds after lift-off a satellite-protective shroud fell off at 23,000') setting back full implementation of Olympus plans.

• **"If adding more directors to a yagi increases gain, why can't a designer keep adding elements for more and more gain?"**
T.I., Dunedin

Each additional director reduces the bandwidth of the antenna. Bandwidth is measured as a percentage of the operating frequency. At 45.25 MHz, a 7 MHz wide channel is 15.47% . At 230 MHz; 3.04%. It takes only 6 to 8 directors at 45.250 MHz to reduce the bandwidth to 7 MHz. At 230 MHz, 22-25 directors equals 7 MHz bandwidth. If there is interest in rolling your own yagis, we'll cover it in a future TB.

Questions for Coop? Address to R.B. Cooper, P.O. Box 330, Mangonui, Far North.

WHAT IS TECH BULLETIN?

Tech Bulletin is the five-time-per-year 'newsletter' created for consultancy clients of Robert B. Cooper. In recognition that VHF/UHF reception and transmission literature / data is often difficult to locate in New Zealand, we make this material available in the hope you as a stockist in television receiving equipment, or an installer of TV receivers or as an aerialist installer will benefit. This is done at the most reasonable cost possible in recognition that per-hour consultancy rates to assist those with television reception problems are unfortunately by their customized nature not affordable in most stockist or aerialist day to day reception situations. To avoid these higher costs associated with researching and answering specific answers to specific problems (on a one-question / one-response basis) Tech Bulletin employs an 'economy of scale' approach. Subject matter is chosen, researched, and presented in the Tech Bulletin format on a five-time-per year schedule.

Tech Bulletin is offered to TV stockists, aerialists and others with an interest in the subject on an annual subscription basis; see next page.

TECH BULLETIN SCHEDULE - ISSUES RELEASED AND PLANNED

TB9301: Co-Channel (interference) elimination; antenna and phasing techniques. *[You are reading this issue]*
TB9302: Weak signal techniques, antenna + masthead practices. [*Issue now available*]
TB9303: UHF techniques, including construction guidance for low-cost UHF parabolic antennas to 6M diameter. [*Release date 15-07-93*]
TB9304: Identifying and correcting television interference problems. [*Release date 15-09-93*].
TB9305: Master/community aerial techniques on a budget; how New Zealand laws govern, how to design and build CATV systems, how to source equipment. *Note*: This is a two-issue series with part-two early in 1994. [*Release date 15-11-93*].

Each issue of TECH BULLETIN focuses on a single topic to provide a thorough schooling in the subject matter chosen. Additional assistance available on a consulting basis.

TO SUBSCRIBE FOR REGULAR SERVICE PLEASE USE FORM ON NEXT PAGE or write Robert B. Cooper, P.O. Box 330, Mangonui, Far North (FAX 09-406-1083).

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6) One-off answer to non-complex problems is available ONLY TO subscribers (for example, see 'ASK COOP' in this issue). Write, enclosing a self-addressed-stamped envelope for reply. Responses prepared on a time-as-available basis.

7) More complex questions involving research time (example: suggesting knife-edge refraction path zones in your region; where to look) are billed at an hourly rate of $75. Write posing question; you will be quoted estimated cost for your approval before work begins.

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